

Updated AGS Proposal to Measure the K_{e3}^+ Decay Rate and Spectrum

February 10, 2000

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Experimental Equipment:

Beamline: Phase 1: C6, Phase 2: C6 or D6, 0.7 GeV/c separated K^+ beam to be stopped in the target.

Detector: NaI calorimeter (Crystal Ball), scintillating fiber target, tracking detector, Čerenkov counter.

Beam time: 2120 hours at 3 - 4 Tp/pulse (Phase 1: 800 h, Phase 2: 1320 h).

Spokesmen:

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CKM Matrix

Relates—

Quark mass eigenstates (d,s,b) of QCD
 \Leftrightarrow Weak mass eigenstates (d',s',b') of SM.

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

$$\text{with } \sum_i V_{ij}^* V_{ik} = \sum_i V_{ji}^* V_{ki} = \delta_{jk}$$

Wolfenstein Form —

$$||V|| = \begin{pmatrix} 1 - \lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1 - \lambda^2/2 & A\lambda^2 \\ A\lambda^3(1 - \rho - i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

$$\lambda \simeq \sin \theta_c \quad (\text{Cabibbo angle})$$

V_{ud} Values

Superaligned Nuclear β Decays

$$\begin{aligned} |V_{ud}| &= 0.9740 \pm 0.0005 \\ \Rightarrow \lambda &= 0.226 \end{aligned}$$

Neutron β Decay

$$\begin{aligned} |V_{ud}| &= 0.9745 \pm 0.0016 \\ \Rightarrow \lambda &= 0.224 \end{aligned}$$

Pion β Decay

$$\begin{aligned} |V_{ud}| &= 0.9743 \pm 0.0056 \\ \Rightarrow \lambda &= 0.225 \end{aligned}$$

Theoretically cleanest, but B.R. $\sim 10^{-8}$.

V_{us} Values and Unitarity

V_{us} from K_{e3}

$$|V_{us}| = 0.2196 \pm 0.0026 \quad (\text{PDG2003})$$

$$|V_{us}| = 0.2270 \pm 0.0020 \quad (\text{Sher, 2002})$$

Theoretically 'cleanest.'

V_{ub}

$$|V_{ub}| = 0.039 \pm 0.011$$

Unitarity Test

$$\begin{aligned} \Delta &= 1 - [|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2] \\ &= 1 - (0.9487 \pm 0.0010) - (0.0482 \pm 0.0010) \\ &\quad - \mathcal{O}(0) \\ &= 0.0031 \pm 0.0014 \end{aligned}$$

Unitarity achieved for $\lambda(K_{e3}) = 0.226$

K^+ Decays

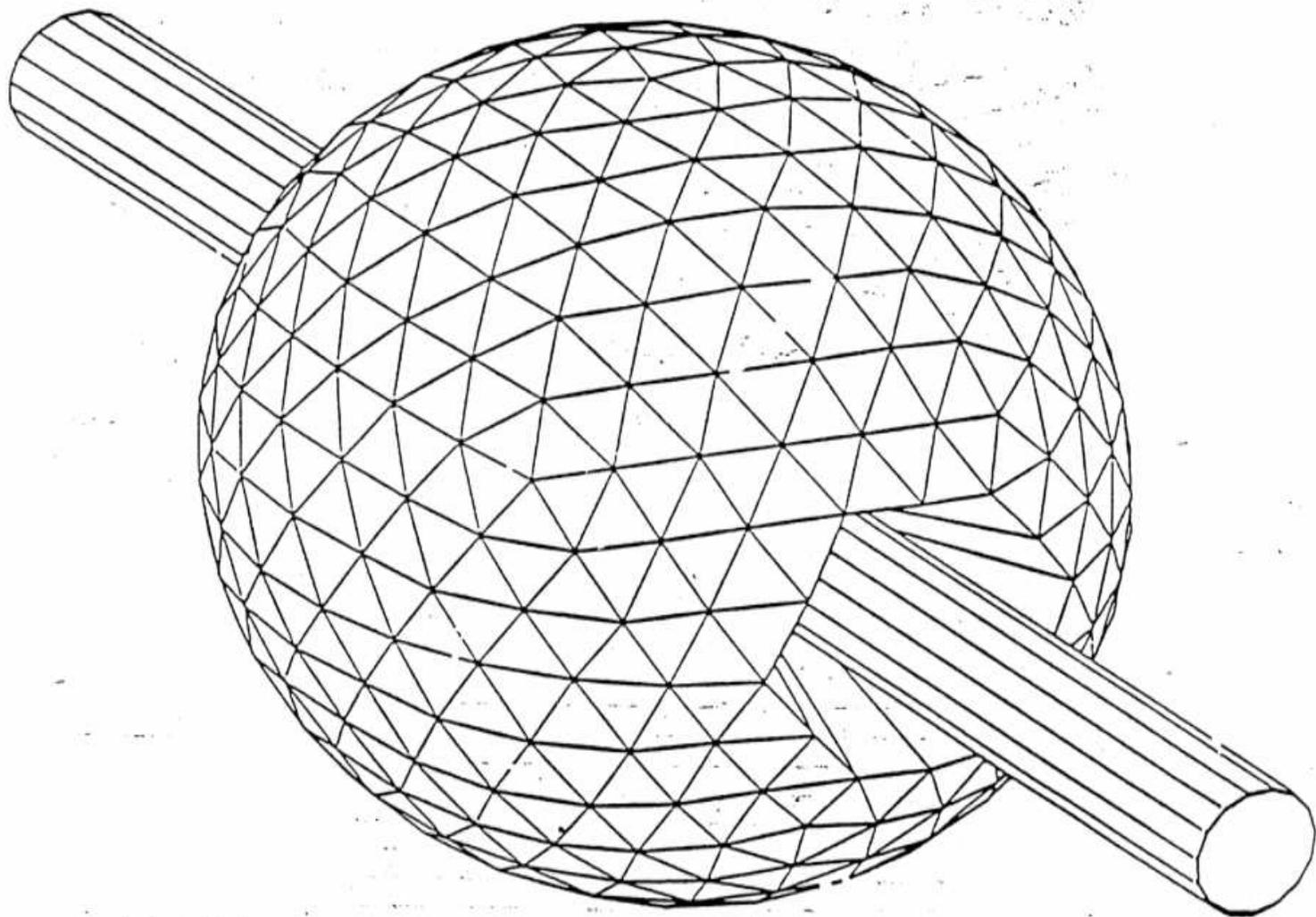
Name	Process	Γ_i/Γ (%)
$K_{\mu 2}$	$\mu^+ \nu_\mu$	63.51 ± 0.18
$K_{\pi 2}$	$\pi^+ \pi^0$	21.16 ± 0.14
K_τ	$\pi^+ \pi^+ \pi^-$	5.59 ± 0.05
$K_{e 3}$	$\pi^0 e \nu_e$	4.82 ± 0.06
$K_{\mu 3}$	$\pi^0 \mu^+ \nu_\mu$	3.18 ± 0.08
$K_{\tau'}$	$\pi^+ \pi^0 \pi^0$	1.73 ± 0.04

All other decays have $\text{BR} < 3 \times 10^{-4} \%$.

Mean $t_{K^+} = 1.2386 \pm 0.0024 \times 10^{-8}$ s.

Crystal Ball

Multi-photon Spectrometer



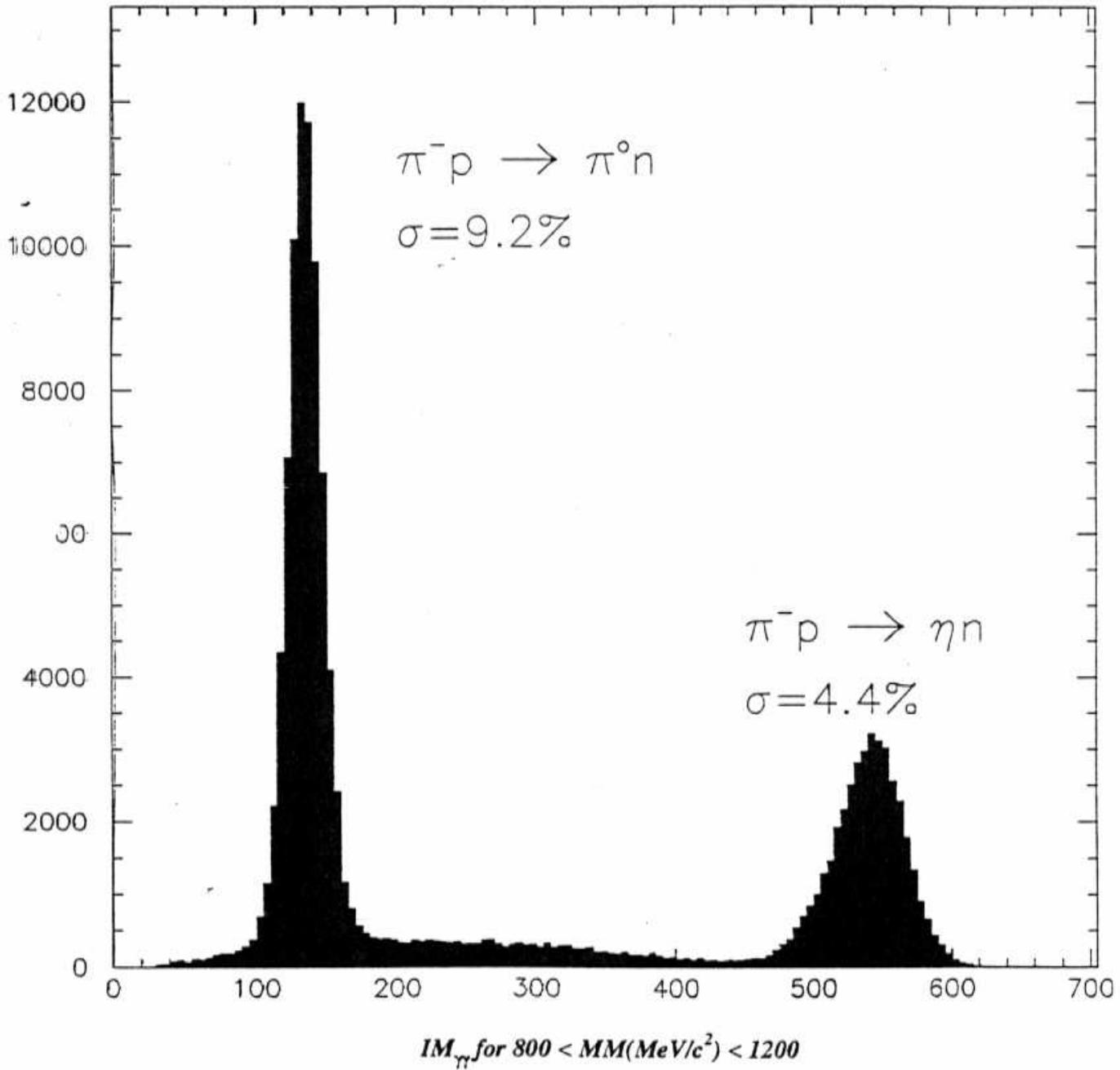
672 separate NaI(Tl) crystals
94% solid angle; with endcaps~98%

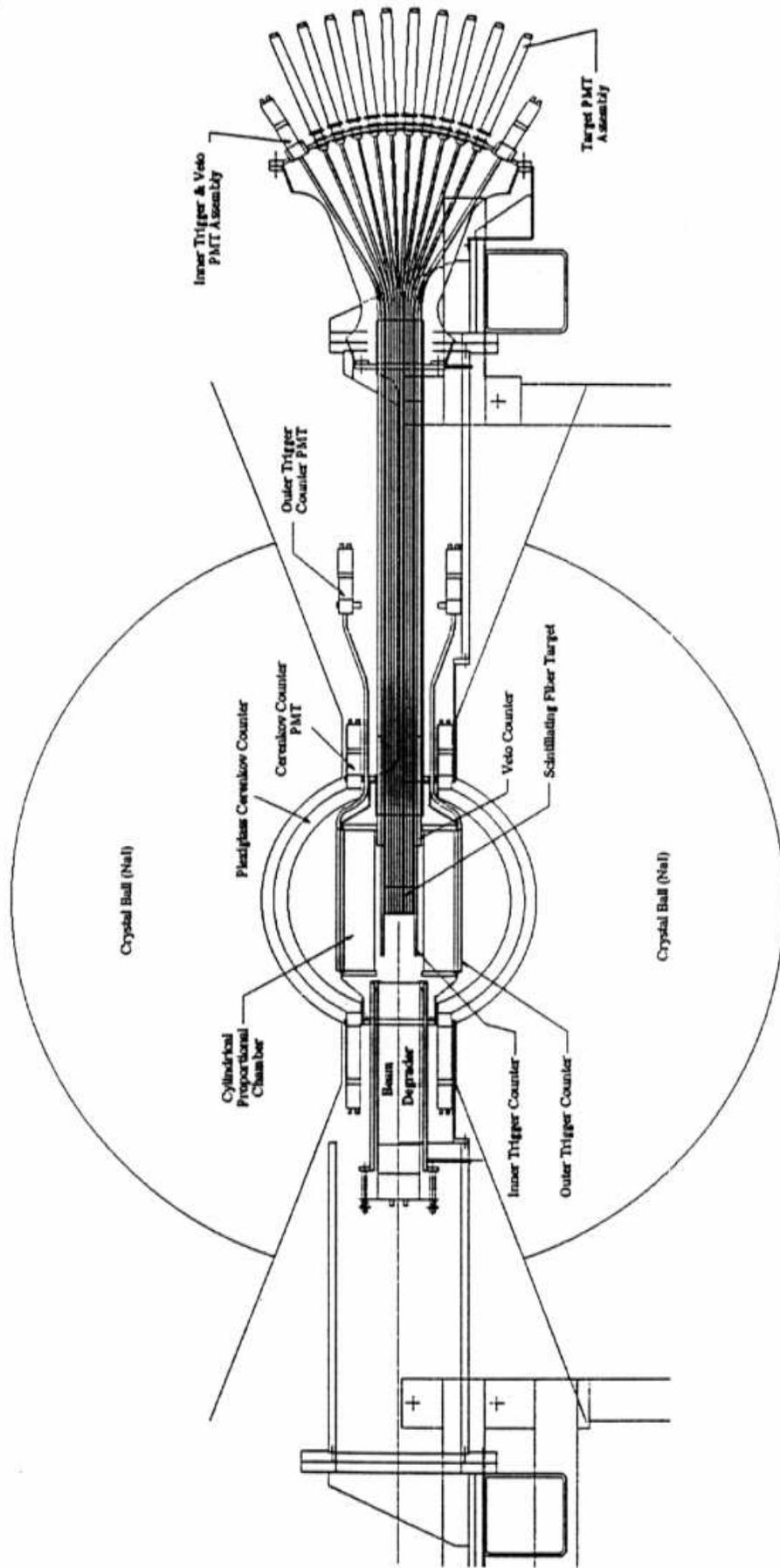
$$\sigma/E = 0.027/\sqrt{E} \quad (E \text{ in GeV})$$

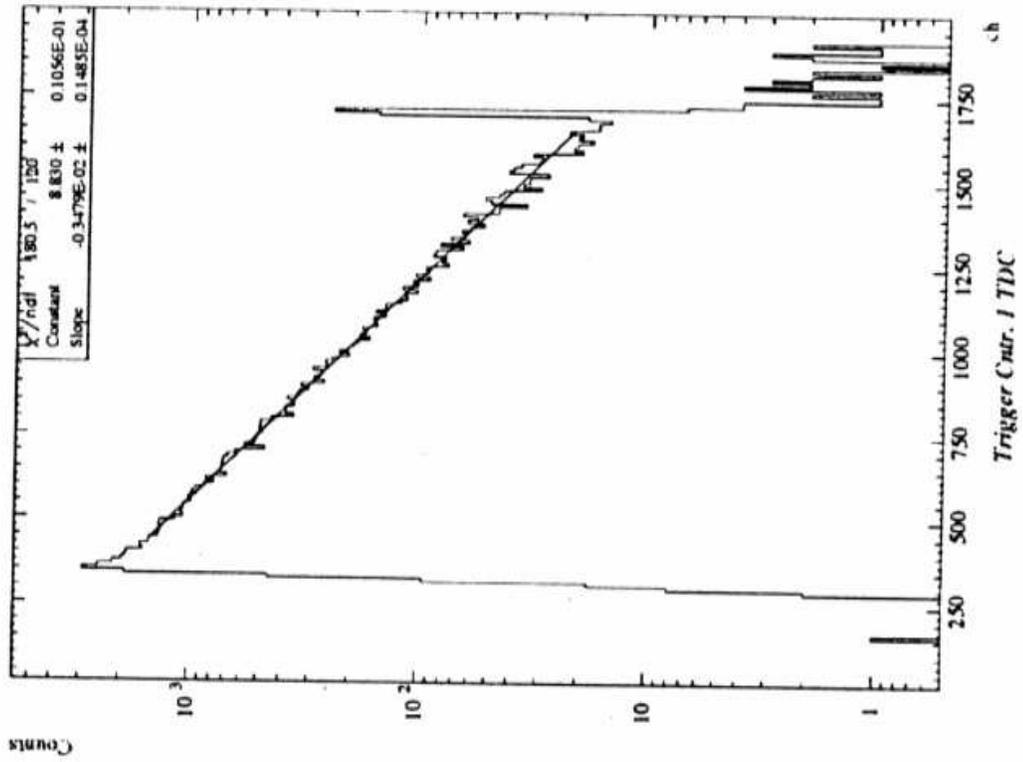
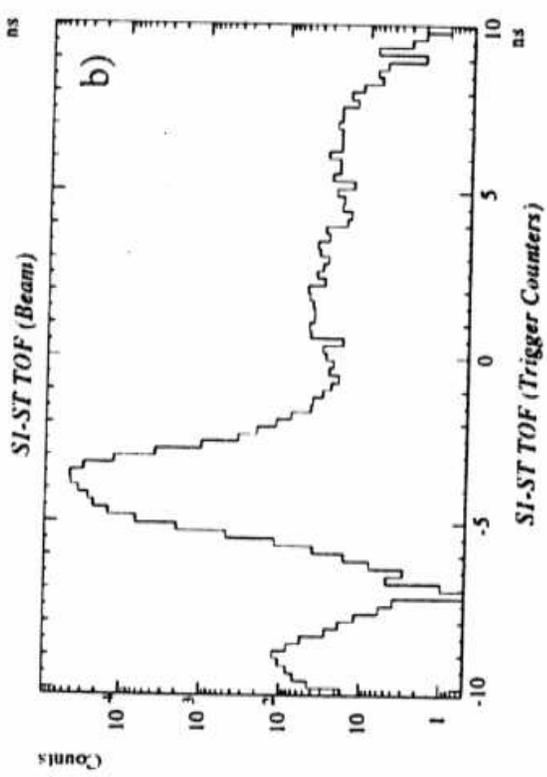
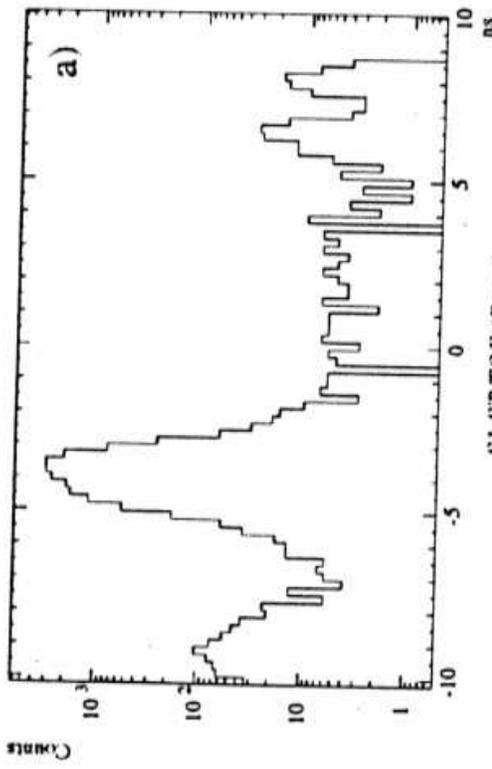
$$\phi_{\text{ext}} = 1.32 \text{ m} \quad \phi_{\text{cavity}} = 0.50 \text{ m} \quad \sigma_{\theta} \approx 2^{\circ}-3^{\circ} \quad \sigma_{\phi} = 2/\sin\theta \quad t = 16 \chi_0$$

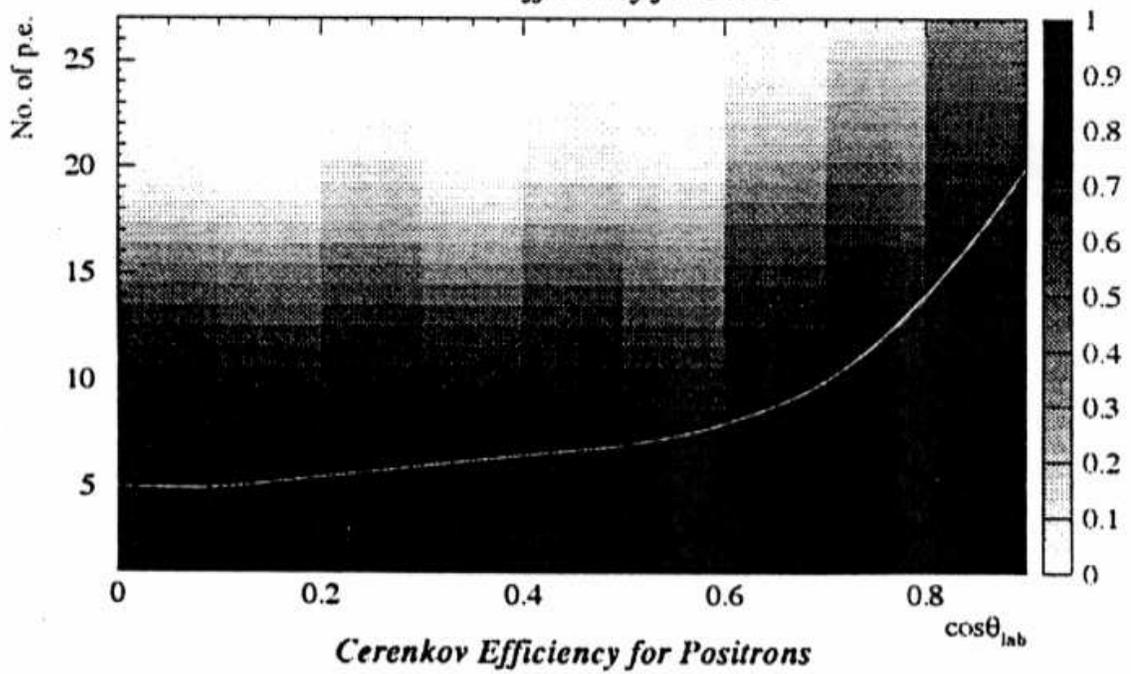
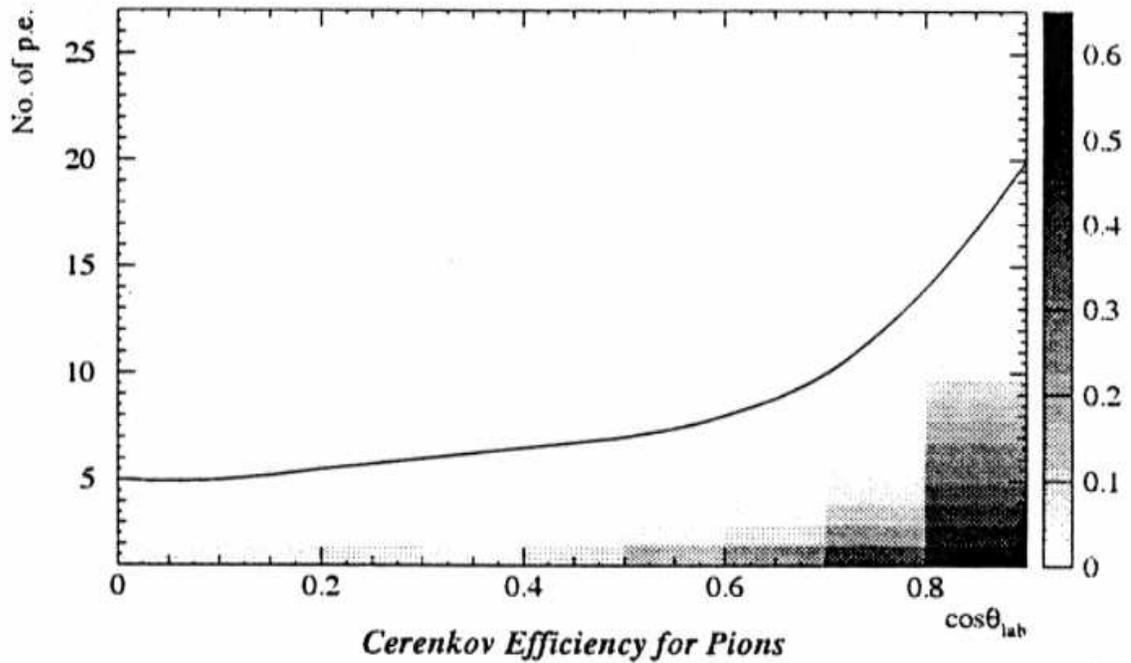
Exp 913

97/10/28 19.22









Extracting the Branching Ratio

$$\text{BR} = \frac{\Gamma(K_{e3})}{\Gamma(\text{total})} = \frac{N_{ke3}/\alpha_0}{\sum_i N_i/\alpha_i}$$

Set $\alpha_i = \alpha_0 (1 + \beta_i)$.

$$\begin{aligned} \text{BR} &= \frac{N_{ke3}}{\sum_i N_i \frac{1}{1+\beta_i}} \simeq \frac{N_{ke3}}{\sum_i N_i (1-\beta_i)} \\ &= \frac{N_{ke3}}{\sum_i N_i - \sum_i N_i \beta_i} = \frac{N_{ke3}}{\sum_i N_i} \frac{1}{1-\delta} \end{aligned}$$

where $\delta = \frac{\sum_i N_i \beta_i}{\sum_i N_i}$.

Need to measure δ to 0.2%.

Systematic Errors

Source	Size (%)
Determination of δ	0.20
Target size for acceptance	0.20
Target size for λ_+	0.34
Particle ID	0.20
Total	0.48

September 17, 2003

Dr. Curt Ekstrom
The Swedborg Laboratory
Uppsala University
Thunbergvagen 5A
S-75121 Uppsala
SWEDEN

Dear Dr. Ekstrom:

I have learned from Joe Comfort of the possibility that the WASA detector is likely to be available for use in experiments at other laboratories within the next 2-3 years. Joe is a spokesman for Experiment E927 at the AGS here, an approved experiment that seeks to obtain a precise value for the V_{ub} CKM matrix element. In spite of difficult funding circumstances experienced by the AGS program in the last couple of years, I would like to state clearly here that BNL continues to stand strongly behind the physics value of E927 and reiterates its continuing, even growing, importance in our understanding of the fundamental parameters of the particle physics Standard Model. The scientific importance of E927 was recognized in October 1996 when it was recommended for approval by the BNL HENP Program Advisory Committee with a science rating of "Compelling". This assessment of its scientific importance remains valid today.

• • •

With the very strong likelihood that BNL will soon begin to receive funding from the National Science Foundation for the two major RSVP experiments, appropriate infrastructure can be put in place to accommodate E927. BNL will work with the E927 Collaboration to seek programmatic funding to restore E927 to the operating schedule for AGS.

• • •

I wish to reiterate my support for the running of E927 and will be interested in considering any possible future hadron physics program. The physics importance of E927 continues to be compelling and, if anything, a successful measurement will become even more important over the next few years. I hope that we will have the opportunity to review the WASA detector in detail, and assist in helping to determine its best scientific use after the completion of the program at your laboratory.

Sincerely,

Thomas B.W. Kirk
Associate Laboratory Director
High Energy and Nuclear Physics

Cc: J. Comfort

The K'_{e4} Reaction with the and Crystal Ball Detector

Spokespersons

J. Comfort, Arizona State University

Chris Allgower, Argonne National Laboratory

Participating Institutions:

Abilene Christian University
Argonne National Laboratory
Arizona State University
Brookhaven National Laboratory
George Washington University
Joint Institute for Nuclear Research, Dubna
Karlsruhe University
Kent State University
Petersburg Nuclear Physics Institute
Rudjer Bošković Institute
University of California, Los Angeles
University of Colorado
University of Maryland
University of Regina
Valpariso University

Decay Branching Ratios

ID	Process	B.R.
K_{e4}	$K^+ \rightarrow \pi^+ \pi^- e^+ \nu$	$3.91 \pm 0.17 \times 10^{-5}$
K'_{e4}	$K^+ \rightarrow \pi^0 \pi^0 e^+ \nu$	$2.10 \pm 0.40 \times 10^{-5}$
K^0_{e4}	$K^0 \rightarrow \pi^0 \pi^- e^+ \nu$	$5.18 \pm 0.29 \times 10^{-5}$
K_{e3}	$K^+ \rightarrow \pi^0 e^+ \nu$	$4.82 \pm 0.06 \times 10^{-2}$

K_{e4} Experimental Data

K_{e4}

L. Rosselet et al., PR D 15, 574 (1977)

30,000 events.

Determined $\delta_0^0 - \delta_1^1 \Rightarrow a_0^0 = 0.26 m_\pi^{-1}$

AGS E865 (1997)

300,000 events.

K'_{e4}

D. Ljung and D. Cline, PR D 8, 1307
(1973)

2 events

V.N. Bolotov et al., SJNP 44, 68 (1986)

27 events

V.V. Barmin et al., SJNP 48, 1032 (1988)

10 events

Goals

1. Test for presence of $L = 2$ waves.
 $L = 0$ for $\pi^0\pi^0$; no $L = 1$.
2. Test $\Delta I = 1/2$ rule.
3. Obtain improved value for f_1 .
Compare to models.
4. Study invariant $M_{\pi^0\pi^0}$ distribution.
Compare to $\pi^-p \rightarrow \pi^0\pi^0n$.

$\Delta I = 1/2$ Rule

$$\Gamma(2\pi^0) = \frac{1}{2} \Gamma(\pi^+\pi^-) - \frac{1}{4} \Gamma(\pi^-\pi^0).$$

PDG96 (Bolotov et al.)

$$1695 \pm 323 = \frac{1}{2} (3157 \pm 137) - \frac{1}{4} (501 \pm 28) \text{ sec}^{-1}$$
$$1.70 \pm 0.32 = 1.45 \pm 0.07 \times 10^3 \text{ sec}^{-1}$$

Barmin et al.

$$2.05 \pm 0.72 = 1.45 \pm 0.07 \times 10^3 \text{ sec}^{-1}$$